

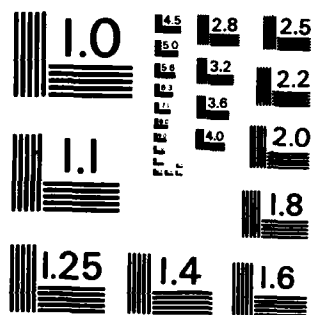
UNCLASSIFIED

F/G 6/16

179

NI

END
DATE
RECEIVED
84
OTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12

USAARL REPORT NO. 84 - 4

**DEVELOPMENT OF A METHOD TO DETERMINE
THE AUDIOGRAM OF THE GUINEA PIG
FOR THRESHOLD SHIFT STUDIES**

By
**Carlos Comperatore
James H. Patterson, Jr.**

SENSORY RESEARCH DIVISION

January 1984

**U.S. ARMY AEROMEDICAL RESEARCH LABORATORY
FORT RUCKER, ALABAMA 36362**

DTIC
ELECTE
S MAR 29 1984 **D**
A

This document has been approved
for public release and sale; its
distribution is unlimited.

USAARL

84 03 28 011



AD A139717

DTIC FILE COPY

NOTICE

Qualified Requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia, 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of Address

Organizations receiving reports from the US Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this report when it is no longer needed. Do not return to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.


Animal Use

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences-National Research Council.

Reviewed:


BRUCE C. LEIBRECHT, PH.D., MAJ, MS
Director, Sensory Research Division

Released for Publication:


J. D. LAMOTHE, PH.D.
LTC, MS
Chairman, Scientific Review
Committee


DUDLEY R. PRICE
Colonel, MC, SFS
Commanding

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAARL Report No. 84-4	2. GOVT ACCESSION NO. AD-A139 717	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Development of a Method to Determine the Audiogram of the Guinea Pig for Threshold Shift Studies		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Carlos Comperatore and James H. Patterson, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Sensory Research Division US Army Aeromedical Research Laboratory Fort Rucker, AL 36362		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102A 3M161102BS10 CB 282
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research and Development Command Fort Detrick Frederick, MD 21701		12. REPORT DATE January 1984
		13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Unlimited		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Noise exposure Hearing Guinea Pig Audiometry		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) See reverse.		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

ABSTRACT: Studies of noise induced threshold shift in guinea pigs require a method to determine the audiogram which meets the following criteria: It must be reliable and permit the determination of threshold at eight to twelve frequencies in a single session lasting less than one hour. A conditioned suppression procedure was adopted to meet these requirements. Three guinea pigs were trained and a series of audiograms determined on each. The audiograms were found to be reliable and in good agreement with published audiograms determined by other methods.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

TABLE OF CONTENTS

	PAGE NO.
List of Tables	1
List of Figures.	2
Introduction	3
Methods and Materials.	4
Results and Discussion	7
Conclusions.	15
References	17
Appendix A. List of Equipment Manufacturers	19

Accession For

NTIS OTHAN ☒

DTIC TAB ☐

Unannounced ☐

Justification ☐

By _____

Distribution/ _____

Availability Codes _____

Dist Avail and/or Special

A1

1
Also
site

LIST OF TABLES

TABLE NO.		PAGE NO.
1	Means and Standard Deviations of the Last Five Audiograms Determined During Audiometric Training of Three Guinea Pigs.	13

LIST OF FIGURES

FIGURE NO.		PAGE NO.
1	Average threshold in dB (SPL) as a function of audiometric training session for four guinea pigs	9
2	Average audiogram for subjects G2, 7C, and 7D determined during training sessions 10 through 14. Vertical bars indicate one standard deviation across subjects.	10
3	Average audiogram for subjects G2, 7C, and 7D determined during training sessions 20 through 24. Vertical bars indicate one standard deviation across subjects.	11
4	Average audiogram for subjects G2, 7C, and 7D determined during last five training sessions. Vertical bars indicate one standard deviation across subjects.	14

INTRODUCTION

The present study was undertaken to establish a method for performing behavioral audiometry on the guinea pig suitable for use in a noise-induced threshold shift experiment. The basic paradigm utilized to determine threshold shift consists of establishing a baseline audiogram before noise exposure and then determining one or more audiograms thereafter. This paradigm places certain constraints on the audiometric procedure which can be used. First, it requires reliability since a succession of audiograms are used to trace the effects of the exposure. Second, the entire audiogram consisting of eight to twelve frequencies must be determined in a single session. Third, the test session should be less than 1 hour in order to permit the detection of effects which are present immediately after the exposure and rapidly disappear. Finally, the reinforcement and motivation used during behavioral training should remain as constant as possible to avoid contaminating the time-varying effects of noise exposure on hearing sensitivity.

Various behavioral methods have been used to measure the guinea pig's auditory threshold. Shock avoidance is a procedure commonly used with other species. In an early attempt to study escape responses present within the guinea pig's behavioral repertoire, Anderson and Wedenberg (1965) signaled electric shock with a tone in an avoidance paradigm. Their results showed that their subjects did not learn to avoid shock even after 3,000 training trials. This finding was attributed to the guinea pig's tendency to become immobile in response to aversive stimulation. Later data on the guinea pig's immobility response (Miller and Murray, 1966) confirmed that shock avoidance training would not result in a consistent response in the presence of auditory stimuli. Capitalizing on the immobility response to aversive stimuli, Anderson and Wedenberg developed a method based on the suppression of an ongoing behavior. In this case, the ongoing behavior consisted of the induction of shivering as a result of being maintained in low environmental temperature. When audible tones, previously paired with shock, were presented, the shivering behavior was suppressed. This paradigm is an adaptation of the conditioned suppression phenomenon previously described by Estes and Skinner (1941). Anderson and Wedenberg exposed guinea pigs to pure tones of 2000 Hz at 60 dB sound pressure level (SPL), with each being followed by a brief electric shock. This training was carried out for six sessions. Shivering then was induced by blowing cold air over the subjects. Audiograms were determined by recording shivering interruptions upon tone presentations. According to Anderson and Wedenberg, reliability of audiograms depended upon maintaining the duration of intertrial intervals at no more than 30 seconds, and actual sessions at 45 minutes or less. In addition, cooling had to be carefully regulated in order to maintain a stable rate of shivering.

In a more recent effort, Crifo (1973) refined the method used by Anderson and Wedenberg by improving the training procedure as well as the testing apparatus. Crifo named this improved method shiver audiometry.

While Crifo's method appears to produce reliable audiograms, methodological difficulties in maintaining low environmental temperatures (0° to 2° Celsius) and in recording the shivering response make this procedure somewhat cumbersome to implement in a noise exposure paradigm.

Miller and Murray (1966) also used a method of suppressing ongoing behavior. They measured guinea pigs' auditory thresholds by presenting pure tones superimposed on ongoing lettuce chewing. Each presentation inhibited chewing, but also resulted in gradual stimulus habituation. Testing ten frequencies in a single session of approximately 60 minutes duration was not considered possible with this method. In addition, the noise of chewing could elevate the measured threshold.

More recently, Prosen et al., (1978) determined threshold for a frequency range between 125 Hz and 52 kHz by using a positive reinforcement training method. In this procedure, tones served as discriminative stimuli for a report response. Guinea pigs first were trained to depress a key with their noses. The key was located to the left of a food magazine. Tone presentations were used as discriminative stimuli to depress a second key located to the right of the food magazine. This response was reinforced and the trial ended. This method yielded more sensitive thresholds below 4.0 kHz than previously published audiograms for guinea pigs (Miller and Murray, 1966; Heffner et al., 1971). Above 4.0 kHz thresholds obtained were comparable to previous data. By this method, Prosen et al., were able to test five to six frequencies per day. While this method appears to produce lower thresholds than previously reported methods, the inability to determine a complete audiogram in a single session suggested that it would not be suitable for noise-induced threshold shift studies.

Also using guinea pigs, Heffner et al., (1971) developed a variation of the conditioned suppression paradigm. Water deprived animals operantly were conditioned to lick a drinking tube for water reinforcement. Tone-shock pairings then were superimposed on this previously trained-licking response. After tone-shock presentations, subjects reduced their licking rate whenever an audible tone was presented. Changes in licking rate as a function of intensity were used to determine thresholds. Since this method provides for stable ongoing behavior, the animals' motivation is under control of the deprivation schedule and the responses are relatively easy to quantify. While none of these procedures yielded complete audiograms in single sessions, the method by Heffner et al., appeared to be most adaptable for threshold shift testing. In this report, the initial audiogram testing method was derived from the basic conditioned suppression response paradigm described by Heffner et al.

METHODS AND MATERIALS

Three albino and three pigmented male guinea pigs, Cavia Parcellus L., of the English variety were obtained from the US Army Aeromedical Research Laboratory (USAAARL) breeding colony to serve as subjects for this study.

Albino guinea pigs G1, G2, and G3 were 7 months old when they entered the study. The three pigmented guinea pigs 7C, 7D, and 7B, were 3 months old at the beginning of the training.

Testing and training sessions were carried out in a sound-treated chamber consisting of a room within-a-room, manufactured by Industrial Acoustics Company.* During testing, subjects were placed in a 20- by 20-cm grid floor cage. An 8- by 8-cm plastic board was attached to the front wall. An orifice in this board allowed the tip of a 7-mm drinking tube to protrude into the experimental cage. Water was supplied to the spout by means of water pressure exerted via a 5-gallon plastic container located 2.5 meters above the floor outside the experimental chamber. Water reinforcement was dispensed by means of an electronic solenoid valve, which in turn was controlled by previously programmed Coulbourn* logic circuit modules. Licking responses were monitored by a Coulbourn counter which was triggered each time the subjects' tongue touched the drinking tube.

During tone presentations, selected frequencies were generated by a Fluke Signal Generator,* model number 6010A. Its output then was driven through a Coulbourn Selectable Envelope-Shaped Rise/Fall Gate, model number 584-04, set for exponential rise/fall. The output of the gate was connected through a Hewlett-Packard* model 350D attenuator to an Altec* model 1954B power amplifier. The output of the amplifier was connected through a Grason-Stadler* model 1293 10 ohm attenuator to an Altec model 604-8H coaxial speaker in a model 612C cabinet. Tones were presented in the experimental chamber via the speaker located 1.1 m from the experimental cage. In addition, an Altec model T0249 monitor speaker was used to monitor each stimulus presentation.

Subjects' activity within the experimental environment was visually monitored via a video camera located inside the chamber. Outside the chamber, a television receiver/monitor was used to display the camera's output.

During training and testing trials, footshocks were administered by means of a Coulbourn shock scrambler, model number E-13-16. In addition, a buzzer, driven through a 1-inch tweeter attached to the side of the cage, was presented at the offset of the shock and replaced the shock when selected by the experimenter. Finally, all stimulus presentations, as well as schedules of reinforcement and suppression ratio calculations, were automatically controlled via a 6800 CPU microprocessor interfaced to the Coulbourn logic modules.

The sound field was calibrated using a Bruel and Kjaer* 1/2-inch condenser microphone; a Bruel and Kjaer-type 2804 battery-powered microphone power supply; a Bruel and Kjaer-type 2606 measuring amplifier and a Federal Scientific* model 440A spectrum analyzer. Measurements of the sound pressure level (SPL) at three locations for each test frequency were made. These locations were chosen to approximate the range of animal head positions which might

*See Appendix A.

occur during licking. The average level at each frequency across all measurement locations was used as the final calibration value.

Initially, the six experimental subjects were exposed to the test environment after 24 hours of complete water deprivation in their home cages. Subjects were placed in the experimental cage and allowed to spontaneously discover the location of the drinking tube. Throughout the first 10 days of training, the licking tube, initially protruding into the experimental cage, gradually was pulled back out of the cage so that it could barely be reached by the subjects' tongue. This procedure prevented animals from biting the drinking tube, and gradually contributed to stabilization of the ongoing licking rate. In addition, another contributing factor to the development of a continuous, uninterrupted, stable licking rate consisted of the implementation of the proper water deprivation schedule. During training days, subjects were allowed to obtain water only from the experimental drinking tube at a fixed ratio (FR) 1 rate. On the nontraining days subjects remained in their home cages and received 30 ml of tap water daily. Consequently, subjects gradually experienced a weight loss from 10% to 23% of their original predeprivation body weight. This deprivation procedure proved adequate throughout training for both the subjects' proper physiological health and the maintenance of the necessary level of motivation to establish a stable licking rate in the course of a 60-minute session. Over the course of the training it was possible to raise the FR schedule of reinforcement to 10 licking responses per reinforcement (FR10).

Audiogram tests were initiated upon the fourth week of training and continued throughout the experiment. For each audiogram, 10 frequencies were tested: 125 Hz, 250 Hz, 500 Hz, 1.0 kHz, 1.4 kHz, 2.0 kHz, 2.8 kHz, 4.0 kHz, 5.7 kHz, and 8.0 kHz. Each session consisted of 100 trials, 10 trials at each of the 10 frequencies. Each trial consisted of a base period of 4.5 seconds during which the subjects' operant licking rate was determined. This was followed by a stimulus presentation interval of 4.5 seconds during which the subjects' licking rate was determined. Each stimulus consisted of a pulsed tone: Three pulses of 750 msec on and 750 msec off per pulse. The stimulus interval was followed by the reinforcement interval, during which an aversive stimulus under the control of the experimenter could be applied. The aversive stimulus, a .7 ma shock, was introduced in 2 of the 10 signal levels tested at each frequency. Footshocks followed tones at high and low levels, so that tones at all levels would become conditioned to shock. As conditioning proceeded, tones always were presented superimposed upon the ongoing licking response. A cessation or reduction of licking rate during the stimulus interval indicated a tone was audible. Each frequency was tested at 10 levels varying in 10 dB steps over a 90 dB range.

On each trial, suppression was quantified by counting the number of licking responses emitted during the base period (P) and the number of responses during the stimulus presentation (W). The suppression ratio then was computed: $SR = W/P+W$. When a suppression is complete, W becomes zero and the suppression ratio becomes zero. When there is no suppression, W is

approximately equal to P and the suppression ratio will be approximately .5. In order to categorize a trial as having shown suppression or not, a criterion value of .25 was adopted. Suppression ratios at or below .25 were interpreted as an indication of active licking suppression in response to signal detection, while values above .25 indicated no suppression, thus poor or no signal detection. The threshold for a test frequency was calculated by linear interpolation between the lowest signal level which yielded the suppression ratio above .25 and the next lower signal level. After a complete audiogram was determined, an index was calculated by averaging the threshold sound pressure levels across frequencies. This average was used as an overall performance measure to assess the progress of training.

RESULTS AND DISCUSSION

During the development of the training method, the deprivation duration and the number of shocks presented during a given session were identified as variables which had to be maintained within specific boundaries. During the first few sessions on which test trials were presented, subjects produced long periods of immobility, apparently in response to the test tones. This response was so persistent that only one or two trials could be presented in the 1 hour allotted to each subject instead of the 100 scheduled. In order to habituate this reaction to the test tones, shock was suspended and tone trials were presented independent of the subjects' licking behavior. After approximately 20 sessions, the immobility response had diminished to a point where shock could be resumed. Then it was decided to administer shocks only in 10% of all trials per session and on one of the 10 levels of each frequency in a random fashion. After several sessions, subjects began to lick through stimulus intervals at tone levels well above threshold. The proportion of shock trials then was gradually increased in an attempt to bring licking suppression under better stimulus control. When the shock density became too high (above 50%), subjects' licking responses became irregular and suppression ratios became unreliable. Therefore, shock densities were maintained between 10 to 20% for the remainder of the experiment.

On the other hand, the water deprivation schedule directly influenced subjects' motivation to develop consistent licking rates. It was noted that 28 hours or more of water deprivation caused subjects to lick at unusually high rates, to rapidly satiate and to cease licking prior to the completion of the full set of test frequencies. Consequently, water deprivation was limited to less than 24 hours.

These early sessions can be considered as pretraining since the data were so erratic that no estimate of the audiograms could be derived. This pretraining phase lasted 54 sessions. During pretraining two subjects, G1 and 7B, were dropped from the study for failing to make progress toward a complete audiogram.

The next 52-55 sessions yielded an estimate of a complete audiogram for subjects 7D, 7C, G2, and G3 on most of the sessions. These sessions we call

audiometric training. To quantify any improvement in the estimated thresholds over training sessions, the "threshold" sound pressure level was averaged across frequencies for each session to produce an average threshold. Figure 1 shows this average threshold as a function of audiometric training session. Subject G3 was dropped from the study after 24 sessions due to inconsistent patterns of responding and increasing numbers of incomplete audiograms.

At first, early threshold estimates were very high. Over the first 14 sessions audiograms improved to an apparent asymptote. The audiograms obtained on training sessions 10 to 14 were averaged for subjects 7D, 7C, and G2 and then means and standard deviations for the group of subjects were computed. Figure 2 shows this average audiogram. For reference, the audiograms reported by Heffner et al., and Prosen et al., are shown in Figure 2. Our audiogram appears to be elevated and shows considerable variability between subjects (large standard deviations).

These results suggested the possibility that our subjects may not have been suppressing licking as a function of conditioned aversiveness of the tones. Close behavioral observations made during training corroborated this suspicion. Subjects were found to behaviorally respond to the onset of a stimulus interval by orienting towards the stimulus source, but resumed licking almost immediately in the case of low intensity stimuli. Consequently, it was possible to infer that the aversive conditioning method used did not produce the necessary conditioning required to suppress the licking behavior long enough to reduce the suppression ratio below .25.

Analysis of the initial training method suggested that the pulsed tones presented during the stimulus interval may have contributed to this apparent lack of conditioning. If each tone pulse (three per stimulus interval) was a separate discriminable event, the occurrence of the shock at the end of three tones on only 10% of the trials resulted in an actual tone-shock pairing on less than 4% of the tones and never on the first or second tone of the trial. This may have been an inadequate shock density to support aversive conditioning of the tones.

Thus, in order to increase the reliability of the tone as a source of information for shock presentations, two modifications of the training method were implemented. Our first step was to replace the pulsed tone stimulus by a single 4.5-s tone. This was done on the fifteenth training session. Then, for approximately 10 sessions, subjects were trained under the same schedule of aversive stimulation as in earlier sessions. This step was a precautionary measure to prevent possible detrimental effects resulting from changing more than one stimulus parameter at a time.

To determine the effect of changing from pulsed to 4.5-s steady tones, an average audiogram was computed on training sessions 20 to 24. These results are shown in Figure 3. There was a slight improvement in the average audiogram and a reduction in the standard deviations. This was primarily due to an improvement in the audiogram of G2 (see Figure 1). However, the group audiogram still is elevated compared to the published

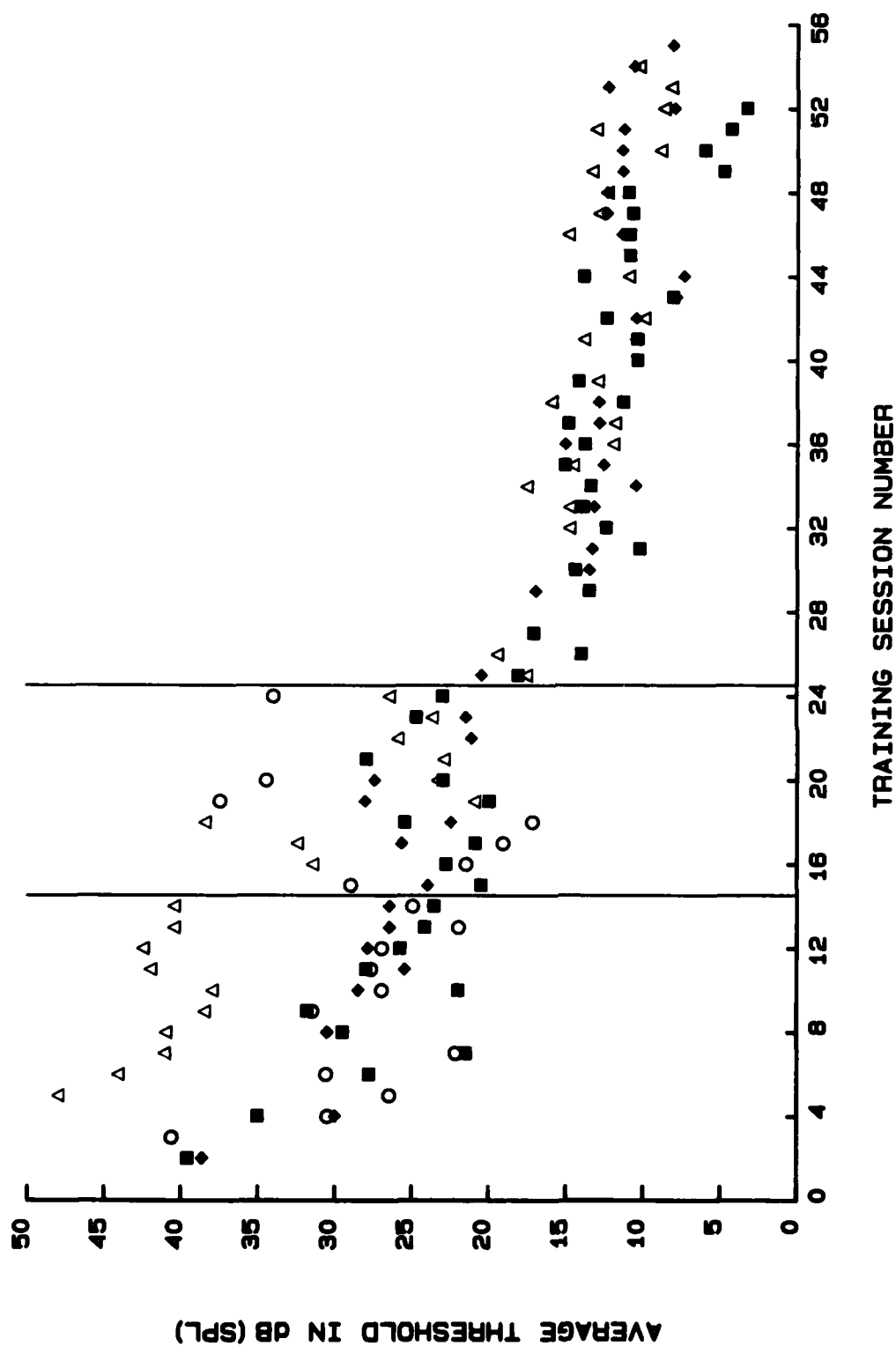


FIGURE 1. Average threshold in dB (SPL) as a function of audiometric training session for four guinea pigs: ◆, /C; ■, 7D; Δ, G2; ○, G3.

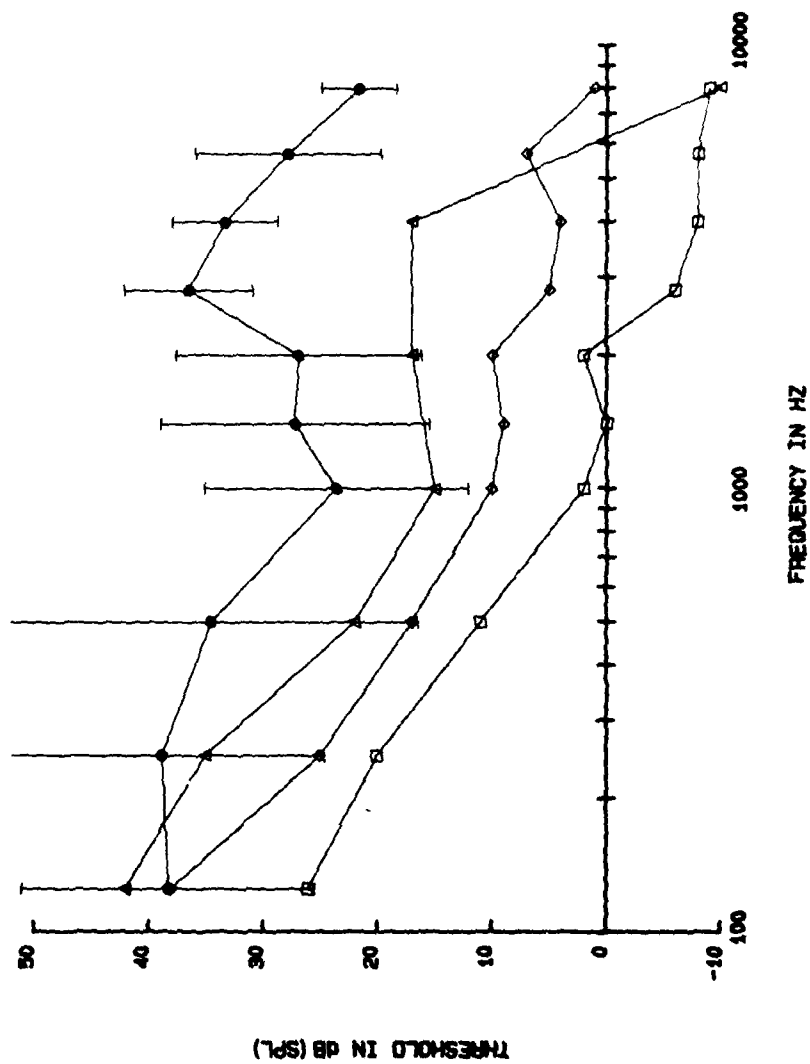


FIGURE 2. Average audiogram for subjects G2, 7C, and 7D determined during training sessions 10 through 14. Closed symbols: ●, present study; Open symbols: Δ, Heffner et al., (1971); ◇, Prosen, et al., (1978); Albino: □, Prosen et al., (1978) Pigmented. Vertical bars indicate one standard deviation across subjects.

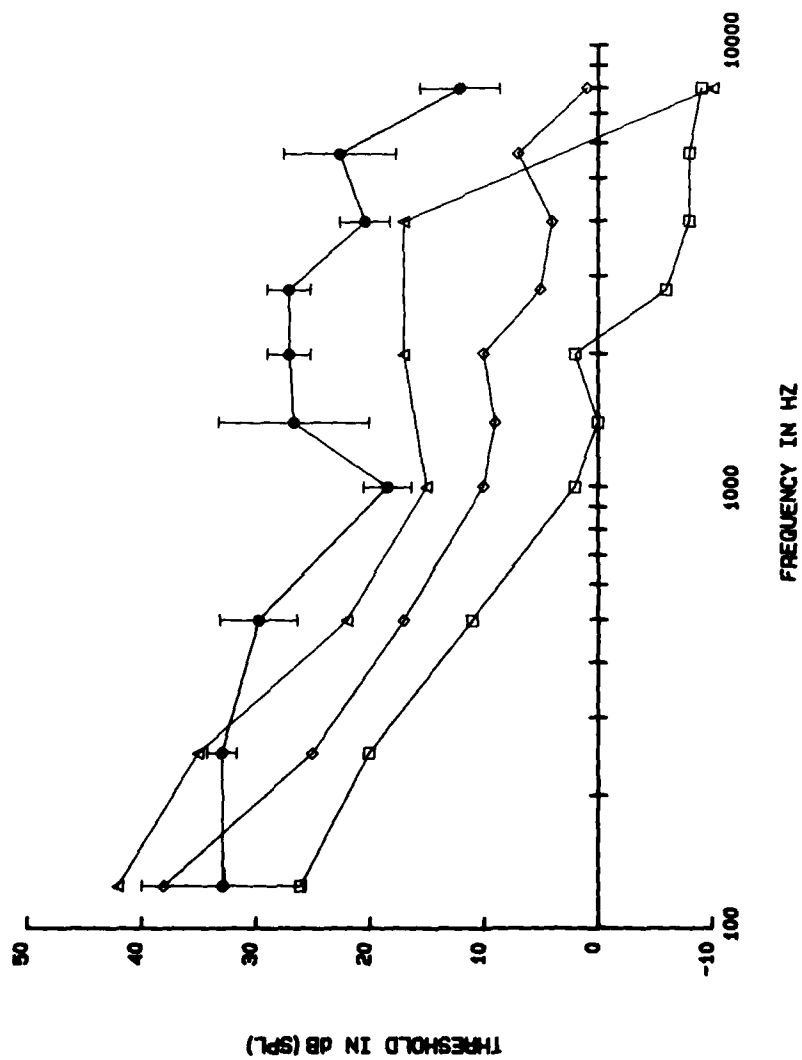


FIGURE 3. Average audiogram for subjects G2, 7C, and 7D determined during training sessions 20 through 24. Closed symbols: ●, present study; Open symbols: Δ, Heffner et al., (1971); ◇, Prosen, et al., (1978), Albino; □, Prosen et al., (1978) Pigmented. Vertical bars indicate one standard deviation across subjects.

results.

At the 25th session, the percentage of tone-shock pairings was increased to 100% by introducing a classical conditioning session prior to the actual audiogram test. Each preaudiogram session consisted of 40 trials. This permitted tone-shock pairing on four intensity levels at each of the ten frequencies. The tones were presented at sound pressure levels equal to and below previously published threshold data by Heffner et al. and Prosen et al.

At the beginning of each classical conditioning session, the drinking tube was hidden in order to prevent the development of any possible contingency between the licking device and shock. Subjects then were exposed to tone-shock pairings until all 40 trials were presented. After a short time-out of approximately 5 minutes, the drinking tube was reintroduced in the experimental environment, thus marking the beginning of the audiogram session. Throughout the testing session, tones were presented at SPL values comparable to those used in the classical conditioning sessions. Footshocks also appeared in levels previously shocked during classical conditioning sessions, but on approximately 50% of all trials. Extinction effects of the testing session were minimized in this manner. In addition, footshocks also were administered contingent on licking during the presentation of a tone. When subjects maintained the licking response throughout a trial, a shock was presented near the offset of the stimulus interval. Then the level tested was considered a training trial and the same intensity level tested once more. If similar results were obtained, the above procedure was repeated for a last time. These results then were recorded and the next two 5 dB steps tested. This procedure provided our testing method with the means to drive our subjects' suppression responses to the lowest possible SPL values.

Examination of Figure 1 shows the improvement in average threshold during sessions 25 to 56 which resulted from this last procedural modification. These results point to a potential methodological pitfall. The occurrence of an apparent asymptote in the average audiogram from the 15th to 25th sessions (Figure 1) could lead to the incorrect conclusion that this is the best audiogram for each subject. Indeed, if the data of Figure 3 are corrected for pinna effects it would be in general agreement with the audiograms obtained by Heffner et al., except at 8000 Hz. However, it is clear that the guinea pig audiogram is significantly better than indicated by this early plateau. The primary methodological difference between the early asymptote and the later one is that the reinforcement contingencies were modified to motivate the subject to produce his "best" audiogram during later sessions. Table 1 contains the means and standard deviations for each subject over the last five audiograms. The standard deviations generally are small, indicating that by this stage in training each subject is producing a reliable audiogram. Figure 4 shows the average audiogram for the group based on these last five training sessions. Note that below 1000 Hz our audiogram is in good agreement with the better of the two groups from Prosen et al. At higher frequencies, our audiogram shows higher threshold values

TABLE 1

MEANS AND STANDARD DEVIATIONS OF THE LAST FIVE AUDIOGRAMS DETERMINED
DURING AUDIOMETRIC TRAINING OF THREE GUINEA PIGS

Subject	Frequency									
	125 Hz	250 Hz	500 Hz	1.0 kHz	1.4 kHz	2.0 kHz	2.8 kHz	4.0 kHz	5.7 kHz	8.0 kHz
62	Mean	21.1	21.8	17.4	14.9	16.2	11.2	3.1	12.9	6.7
	S.D.	5.5	4.5	2.2	2.7	2.2	2.7	3.5	4.2	2.7
7C	Mean	23.2	18.2	16.0	14.9	13.2	10.2	6.1	6.1	3.7
	S.D.	2.7	3.5	2.7	2.7	2.2	2.7	2.7	2.7	7.1
7D	Mean	22.2	20.8	16.4	10.9	14.2	6.2	2.1	6.6	6.7
	S.D.	2.7	2.7	2.7	4.2	4.5	2.7	8.2	4.7	2.7

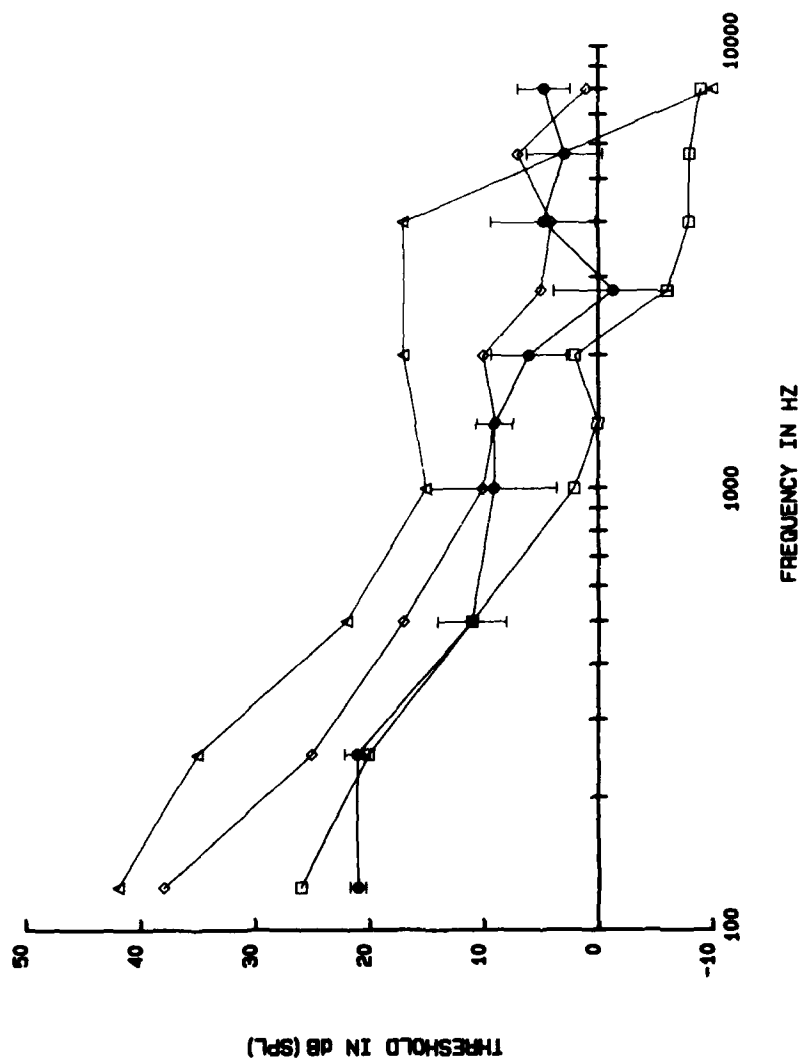


FIGURE 4. Average audiogram for subjects G2, 7C, and 7D determined during last five training sessions. Closed symbols: ●, present study; Open symbols: Δ, Heffner et al., (1971); ◇, Prosen, et al., (1978), Albino; □, Prosen et al., (1978) Pigmented. Vertical bars indicate one standard deviation across subjects.

than their better group.

The elevated thresholds at higher frequencies probably are a result of the arrangement of the sound source and the test cage. The speaker was located at approximately 135° to the right of the subject while he was licking, i.e., to the side and behind the subject. This orientation would provide a "shadowing" of the higher frequencies by the pinna. The pinna effect is estimated to be on the order of 5 dB (Sinyor and Laszlo, 1973). With this correction, our audiogram would approach the better audiogram reported by Prosen et al.

CONCLUSIONS

Complete 10-frequency audiograms were obtained in less than 1 hour. The audiograms produced by this conditioned suppression method are in good agreement with published audiograms for guinea pigs. The audiometric data produced by this method appear to be stable over weeks, permitting the determination of recovery from threshold shift functions.

REFERENCES

- Anderson, H. and Wedenberg, E. A. 1965. A new method for hearing tests in the guinea pig. *Acta Oto-Laryngologica*. 60, 375-393.
- Crifo, S. 1973. Shiver-audiometry in the conditioned guinea pig (simplified Anderson-Wedenberg test). *Acta Oto-Laryngologica*. 75, 38-44.
- Estes, W. K. and Skinner, B. F. 1941. Some quantitative properties of anxiety. *Journal of Experimental Psychology*. 29, 390-400.
- Heffner, R., Heffner, H. and Masterton, B. 1971. Behavioral measurements of absolute and temporary difference thresholds in guinea pigs. *Journal of the Acoustical Society of America*. 49:1888-1895.
- Miller, J. D. and Murray F. S. 1966. Guinea pig's immobility response to sound: threshold habituation. *Journal Comparative and Physiological Psychology*. 61, 227-233.
- Prosen, C. A., Peterson, M. O., Moody, D. B. and Stebbins, W. C. 1978. Auditory thresholds and kanamycin-induced hearing loss in the guinea pig assessed by a positive reinforcement procedure. *Journal of the Acoustical Society of America*. 63, 559-566.
- Sinyor, A. and Laszlo, C. A. 1973. Acoustic behavior of the outer ear of the guinea pig and the influence of the middle ear. *Journal of the Acoustical Society of America*. 54, 916-921.

LIST OF MANUFACTURERS

Altec Lansing Corporation
1515 S. Manchester Avenue
Anaheim, CA 92803

Bruel and Kjaer Instruments, Incorporated
9047-A Gaither Road
Gaithersburg, MD 20760

Coulbourn Instruments
Box 2551
Lehigh Valley, PA 18001

Federal Scientific
615 West 131st Street
New York, NY 10027

Grason-Stadler
56 Winthrop Street
Concord, MA 01742

Hewlett-Packard
P.O. Box 28234
450 Interstate North
Atlanta, GA 30328

Industrial Acoustics Company, Incorporated
380 Southern Boulevard
Bronx, NY 10454

John Fluke Manufacturing Company, Incorporated
P.O. Box 43210
Mountlake Terrace, WA 98043

INITIAL DISTRIBUTION

Commander
US Army Natick R & D Command
ATTN: Tech Librarian
Natick, MA 01760

Commander
US Army Research Institute of
Environmental Medicine
Natick, MA 01760

US Navy
Naval Sub Med Rsch Lab
Med Library, Naval Submarine Base
Box 900
Groton, CT 06340

US Army Avionics R & D Activity
ATTN: DAVAA-O
Fort Monmouth, NJ 07703

Cdr/Dir
US Army Combat Surveillance &
Target Acquisition Lab
ATTN: DELCS-D
Fort Monmouth, NJ 07703

US Army R & D Technical
Support Activity
Fort Monmouth, NJ 07703

Commander
10th Medical Laboratory
ATTN: DEHE (Audiologist)
APO New York 09180

Chief
Benet Weapons Laboratory
LCWSL, USA ARRADCOM
ATTN: DRDAR-LCB-TL
Watervliet Arsenal
Watervliet, NY 12189

Commander
Naval Air Development Center
Biophysics Lab (ATTN: George Kydd)
Code 60B1
Warminster, PA 18974

Human Factors Engr Div
Acft & Crew Systems Tech Dir
Naval Air Development Center
Warminster, PA 18974

Naval Air Development Center
Tech Info Div
Technical Support Department
Warminster, PA 18974

Commander
Naval Air Development Center
ATTN: Code 6022 (Mr. Brindle)
Warminster, PA 18974

Dr. E. Hendler
Code 6003
Naval Air Development Center
Warminster, PA 18974

Director
Army Audiology & Speech Center
Walter Reed Army Medical Center
Forest Glen Section, Bldg 156
Washington, DC 20012

Director
Walter Reed Army Institute
of Research
Washington, DC 20012

Commander
US Army Institute of
Dental Research
Walter Reed Army Medical Center
Washington, DA 20012

Uniformed Services University
of the Health Sciences
4301 Jones Bridge Road
Bethesda, MD 20014

Commanding Officer
Naval Medical R & D Command
National Naval Medical Center
Bethesda, MD 20014

Under Secretary of Defense for
Research and Engineering
ATTN: Mil Asst for Medical
and Life Sciences
Washington, DC 20301

Director of Professional Services
Office of The Surgeon General
Department of the Air Force
Washington, DC 20314

Naval Air Systems Command
Tech Library Air 950D
Rm 278, Jefferson Plaza II
Department of the Navy
Washington, DC 20361

US Navy
Naval Research Lab Library
Code 1433
Washington, DC 20375

US Navy
Naval Research Lab Library
Shock & Vibration Info Ctr
Code 8404
Washington, DC 20375

Harry Diamond Laboratories
Scientific & Technical
Information Offices
2800 Powder Mill Road
Adelphi, MD 20783

Director
US Army Human Engineering
Laboratory
ATTN: Tech Library
Aberdeen Proving Ground, MD
21005

US Army Material Systems
Analysis Agency
ATTN: Reports Dist
Aberdeen Proving Ground, MD
21005

US Army Ordnance Center
and School
Library, Bldg 3071
ATTN: ATSL-DOSL
Aberdeen Proving Ground, MD
21005

Director
Ballistics Research Lab
ATTN: DRDAR-TSB-C (STINFO)
Aberdeen Proving Ground, MD
21005

US Army Environmental Hygiene
Agency Library, Bldg E2100
Aberdeen Proving Ground, MD
21010

Commander
US Army Med Rsch Institute
of Chemical Defense
Aberdeen Proving Ground, MD
21010

Technical Library
Chemical Systems Laboratory
Aberdeen Proving Ground, MD 21010

Commander
US Army Medical R & D Command
ATTN: SGRD-SI (Mrs. Madigan)
Fort Detrick
Frederick, MD 21701

Commander
US Army Med Rsch Institute
of Infectious Diseases
Fort Detrick
Frederick, MD 21701

Commander
US Army Med Bioengineering
R & D Laboratory
Fort Detrick
Frederick, MD 21701

Dir of Biol & Med Sciences Div
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

Defense Technical
Information Center
Cameron Station, VA 22314

US Army Material Development &
Readiness Command
ATTN: DRCSG
5001 Eisenhower Avenue
Alexandria, VA 22333

US Army Foreign Science &
Technology Center
ATTN: DRXST-IS1
220 7th Street, NE
Charlottesville, VA 22901

Commander
US Army Transportation School
ATTN: ATSP-TD-ST
Fort Eustis, VA 23604

Commander
US Army Airmobility Laboratory
ATTN: Library
Fort Eustis, VA 23604

US Army Training and
Doctrine Command
ATTN: ATCD
Fort Monroe, VA 23651

Commander
US Army Training and
Doctrine Command
ATTN: Surgeon
Fort Monroe, VA 23651

US Army Research and
Technology Laboratory
Structures Laboratory Library
NASA Langley Research Center
Mail Stop 266
Hampton, VA 23665

US Navy
Naval Aerospace Medical
Institute Library
Bldg 1953, Code 102
Pensacola, FL 32508

US Air Force
Armament Development and
Test Center
Eglin Air Force Base, FL 32542

Colonel Stanley C. Knapp
US Central Command
CCSG MacDill AFB, FL 33608

Redstone Scientific Information
Center
DRDMI-TBD
US Army Missile R & D Command
Redstone Arsenal, AL 35809

Air University Library
(AUL/LSE)
Maxwell AFB, AL 36112

Commander
US Army Aeromedical Center
Ft Rucker, AL 36362

Commander
US Army Avn Center &
Fort Rucker
ATTN: ATZQ-CDR
Ft Rucker, AL 36362

Director
Directorate of Combat
Developments
Bldg 507
Ft Rucker, AL 36362

Director
Directorate of Training
Development
Bldg 502
Ft Rucker, AL 36362

Chief
Army Research Institute
Field Unit
Ft Rucker, AL 36362

Commander
US Army Safety Center
Ft Rucker, AL 36362

Commander
US Army Aviation Center
& Fort Rucker
ATTN: ATZQ-T-ATL
Ft Rucker, AL 36362

Commander
US Army Aircraft
Development Test Activity
ATTN: STEBG-MP-QA
Cairns AAF
Ft Rucker, AL 36362

President
US Army Aviation Board
Cairns AAF
Ft Rucker, AL 36362

Canadian Army Liaison Officer
Bldg 602
Ft Rucker, AL 36362

Netherlands Army Liaison Office
Bldg 602
Ft Rucker, AL 36362

German Army Liaison Office
Bldg 602
Ft Rucker, AL 36362

British Army Liaison Office
Bldg 602
Ft Rucker, AL 36362

French Army Liaison Office
Bldg 602
Ft Rucker, AL 36362

US Army Research and
Technology Labs
Propulsion Laboratory MS 77-5
NASA Lewis Research Center
Cleveland, OH 44135

Human Engineering Division
Air Force Aerospace Medical
Research Laboratory
ATTN: Technical Librarian
Wright Patterson AFB, OH
45433

US Air Force Institute of
Technology (AFIT/LDE)
Bldg 640, Area B
Wright-Patterson AFB, OH 45433

John A. Dellinger, MS, ATP
Univ of Ill - Willard Airport
Savoy, IL 61874

Henry L. Taylor
Director
Institute of Aviation
Univ of Ill - Willard Airport
Savoy, IL 61874

Commander
US Army Troop Support and
Aviation Material Readiness Cmd
ATTN: DRSTS-W
St Louis, MO 63102

Commander
AVRADCOM
ATTN: SGRD-UAX-AL (Maj Lacy)
Bldg 105
4300 Goodfellow Boulevard
St Louis, MO 63166

Commander
US Army Aviation R & D Command
ATTN: DRDAV-E
4300 Goodfellow Blvd
St Louis, MO 63166

Commander
US Army Aviation R & D Command
ATTN: Library
4300 Goodfellow Blvd
St Louis, MO 63166

Commanding Officer
Naval Biodynamics Laboratory
PO Box 24907
Michoud Station
New Orleans, LA 70129

Federal Aviation Administration
Civil Aeromedical Institute
ATTN: Library
Box 25082
Oklahoma City, OK 73125

US Army Field Artillery School
ATTN: Library
Snow Hall, Room 14
Fort Sill, OK 73503

Commander
US Army Academy of Health Sciences
ATTN: Library
Ft Sam Houston, TX 78234

Commander
US Army Health Services Command
ATTN: Library
Ft Sam Houston, TX 78234

Commander
US Army Institute of
Surgical Research
Ft Sam Houston, TX 78234

US Air Force
Aerospace Medical Division
School of Aerospace Medicine
Aeromedical Library/TSK-4
Brooks AFB, TX 78235

US Army
Dugway Proving Ground
Technical Library
Bldg 5330
Dugway, UT 84022

Dr. Diane Damos
Psychology Department
Arizona State University
Tempe, AZ 85287

US Army Yuma Proving Ground
Technical Library
Yuma, AZ 85364

US Army White Sands Missile Range
Technical Library Division
White Sands Missile Range
New Mexico, 88002

US Air Force
Flight Test Center
Technical Library, Stop 238
Edwards AFB, CA 93523

US Army Aviation Engineering
Flight Activity
ATTN: DAVTE-M (Tech Lib)
Edwards AFB, CA 93523

US Navy
Naval Weapons Center
Tech Library Division
Code 2333
China Lake, CA 93555

US Army Combat Developments
Experimental Command
Technical Library
Hq, USACDEC
Box 22
Ft Ord, CA 93941

Aeromechanics Laboratory
US Army Rsch & Tech Labs
Ames Research Center, M/S 215-1
Moffett Field, CA 94035

Commander
Letterman Army Institute of Rsch
ATTN: Med Rsch Library
Presidio of San Francisco
CA 94129

Sixth US Army
ATTN: SMA
Presidio of San Francisco
CA 94129

Director
Naval Biosciences Laboratory
Naval Supply Center, Bldg 844
Oakland, CA 94625

Col F. Cadigan
DAO-AMLOUS B
Box 36, US Embassy
FPO New York 09510

Staff Officer, Aerospace Medicine
RAF Staff
British Embassy
3100 Massachusetts Ave, NW
Washington, DA 20008

Department of Defence
R.A.N. Rsch Laboratory
P.O. Box 706
Darlinghurst, N.S.W. 2010
Australia

Canadian Society of Avn Med
c/o Acad of Med, Toronto
ATTN: Ms Carmen King
288 Bloor Street West
Toronto, Ontario
M5S 1V8

Canadian Air Line Pilot's Assn
MAJ J. Soutendam (Ret)
1300 Steeles Ave East
Brampton, Ontario, Canada
L6T 1A2

Canadian Forces Med Ln Off
Canadian Defence Ln Staff
2450 Massachusetts Ave, NW
Washington, DC 20008

Commanding Officer
404 Maritime Training Squadron
Canadian Forces Base Greenwood
Greenwood, N.S. BOP 1N0 Canada
ATTN: Aeromed Tng Unit

Officer Commanding
School of Operational and
Aerospace Medicine
DCIEM
PO Box 2000
1133 Sheppard Avenue West
Downsview, Ontario, Canada
M3M 3B9

National Defence Headquarters
101 Colonel By Drive
Ottawa, Ontario, Canada
K1A 0K2
ATTN: DPM

